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J.M.C. opening addresses

INTRODUCTORY LECTURE

TO THE

COURSE OF CHEMISTRY,

IN

JEFFERSON MEDICAL COLLEGE,

DELIVERED NOV. 6, 1843.

BY

FRANKLIN BACHE, M.D.

PUBLISHED BY THE CLASS.

PHILADELPHIA:
MERRIHEW AND THOMPSON, PRINTERS,
No. 7 Carter's Alley.
.....
1843.

CORRESPONDENCE.

PHILADELPHIA, Nov. 20th, 1843.

Prof. FRANKLIN BACHE;

DEAR Sir,—At a meeting of the students of Jefferson Medical College, Nov. 14, 1843, W. W. TOWNSEND, of Pa., in the chair, J. F. MILLER, of Ala., was elected secretary, and the undersigned were appointed a committee to address you in behalf of the Class, requesting for publication a copy of your very eloquent Introductory Lecture to the branch that has in this school been so happily given to your charge.

Permit us, Sir, to present to you for the Class their high regards and esteem.

W. A. BOYD, N. C.
C. H. BRESSLER, Philada.
W. J. WOODS, S. C.
FREDERIC ROBIE, Me.
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S. EMANUEL, Miss.
J. P. COLGAN, Del.
G. E. OUTHIT, Nova Scotia.

S. G. BAILEY, N. Y., *Sec. Committee.*

November 20th, 1843.

GENTLEMEN,—I have just received your note, requesting, in behalf of the Class of Jefferson Medical College, a copy of my Introductory Lecture for publication. I cheerfully acquiesce in your request, and place the manuscript at your disposal.

I am, Gentlemen,

Your sincere friend,

FRANKLIN BACHE.

To Messrs. W. A. BOYD, C. H. BRESSLER, and others,
Committee of the Medical Class of Jefferson College.

INTRODUCTORY.

The revolution of the seasons has brought us once more to that period when it becomes my duty to open my annual course of lectures in this College. Twenty-one years have now elapsed since I commenced my career as a chemical lecturer; and although I have, during that period, delivered many private courses, as well as a number of public ones, in fulfillment of my successive appointments as professor in the Franklin Institute and College of Pharmacy of this city, still I never meet my class, to deliver my opening address, with perfect calmness and self-possession. I find myself surrounded by students from almost every state of the Union, all having the same object in view—the acquisition of knowledge to fit them for the exercise of an important profession. Some of you are here for the purpose of renewing and perfecting the instruction received in this College in former years; a much larger number is in our halls for the first time, willing, with generous confidence, to trust in our abilities as medical teachers. Under these circumstances, can I fail to remember that, in the scheme of instruction, an important branch of science is allotted to me to teach; and is it surprising that I should feel, on an occasion like the present, my responsibilities as an instructor with peculiar force? To you all, gentlemen, I tender a cordial welcome; and in the prosecution of our common object, the cultivation of medical science, let us here, at the very threshold of our labours, pledge ourselves to the exercise of diligence, zeal, and mutual good feeling.

Chemistry may be regarded in the two-fold light of a pure science, and of a science applied to some useful purpose. As a pure science it treats of the reactions of matter, as exerted between its particles when in real or apparent

contact, and of the general principles and laws deducible from these reactions. It embraces, therefore, a systematic view of the different kinds of matter, whether simple or compound, considered with reference to the mutual attractions of their atoms, or minutest particles. As an applied science, it speaks of those chemical actions and processes which illustrate other sciences, or form steps in particular arts. Hence have arisen several divisions of applied chemistry; as technical chemistry, when the science is applied to the arts generally, agricultural chemistry, when its principles are made to bear on agriculture, and medical chemistry, when its application is made to medicine and pharmacy.

But it must not be supposed that chemistry, as applied to any particular science or art, can be taught independently of pure chemistry, or what may be called the philosophy of chemistry. On the contrary, no chemical manipulation or process can be explained without a resort to principles; and to comprehend these it is necessary to go to the very foundations of the science. Thus, it may be truly affirmed that it would be impossible to impart a knowledge of the different chemical products used in medicine, by describing them in succession, without taking, at the same time, a systematic view of chemical bodies generally. The facts would be so loosely bound together without the cement of principles, that it would be difficult, not to say impossible, to recollect them. Hence it becomes necessary, in teaching chemistry as applied to medicine, to take a systematic view of the whole science; but, in doing this, it by no means follows that the same attention must be paid to every portion of the subject. On the contrary, substances which are remotely connected with medicine may be slightly touched upon; while others, a knowledge of which is important to the physician, can be noticed in detail.

Now it is on this plan that I propose to conduct the ensuing course of lectures. But, in carrying it into effect, it is encouraging to observe how numerous are the substances, both sim-

ple and compound, connected with medicine. Thus, among the simple bodies which are used in an uncombined state, we have sulphur, chlorine, iodine, bromine, and carbon or charcoal, together with several of the metals; and the pharmaceutical compounds furnished by chemistry are so diversified, that every division and subdivision of the science furnishes a quota, more or less numerous and important. Among the oxides we have water, potassa, lime, magnesia, and the oxides of iron, zinc, lead, mercury, and antimony; among the chlorides, those of sodium, barium, calcium, zinc, and antimony, together with calomel and corrosive sublimate; among the iodides, those of sulphur, potassium, iron, zinc, mercury, lead, silver, and arsenic; and among the sulphurets, those of potassium, iron, mercury, and antimony. In relation to the acids, we find medicine and pharmacy more or less concerned with the sulphuric, phosphoric, muriatic, hydriodic, hydrocyanic, nitric, nitrous, carbonic, arsenious, oxalic, acetic, tartaric, citric, benzoic, and tannic acids. Again, medicine is connected with a numerous catalogue of salts, among which may be enumerated the sulphate of potassa, or vitriolated tartar; sulphate of soda, or Glauber's salt; sulphate of magnesia, or Epsom salt; sulphate of iron, or green vitriol; sulphate of zinc, or white vitriol; muriate of ammonia, or sal ammoniac; nitrate of potassa, or nitre; nitrate of silver, or lunar caustic; carbonate of ammonia, or mild volatile alkali; carbonate of potassa, or salt of tartar; carbonate of magnesia, or lump magnesia; subcarbonate of iron, or precipitated oxide of iron; carbonate of zinc, or calamine, and carbonate of lead, or white lead. Besides these, there are employed in medicine or pharmacy, the ferrocyanurets of potassium and iron; the borate of soda, or borax; the arsenite and arseniate of potassa; the acetates of ammonia, potassa, soda, zinc, lead, copper, and mercury, and the tartrate and bitartrate of potassa. To these may be added the double salts, alum, Rochelle salt, and tartar emetic. Long as this catalogue may appear, it is yet far from embracing all the chemical preparations connected with the healing art.

If we turn our attention to vegetable substances, the connection between chemistry and medicine will be no less manifest. We have already enumerated some of the vegetable acids connected with medicine; but the importance of a knowledge of vegetable substances rests upon a much wider basis. The organic alkalies are far more important. Among these are included those invaluable medicines, quinia and morphia. By the discovery of this important class of compounds, embracing more than twenty distinct substances, the chemist has made a contribution to the Materia Medica of inestimable value.

The department of vegetable chemistry embraces many other substances, important in a remedial and pharmaceutical point of view. As such we may enumerate ether, the fixed and volatile oils, wax, animal fats, sugar, starch, and gum. The spontaneous chemical changes which take place in vegetables, comprising the vinous and acetous fermentations, also deserve the particular attention of the medical student.

From what has been said, it must be apparent that the physician must be a thorough-bred chemist; otherwise he is but half taught. At the same time it must be evident that there is hardly a department or division of chemistry, which is not connected directly or indirectly with his profession. In pursuing, therefore, a systematic course in the science, we can hardly proceed a single step in our explanations, without meeting with some fact which has a bearing on medicine; and, consequently, those portions of the ensuing lectures, which have no medical applications, and which are retained for the purpose of preserving the chain of connection between the different parts of the subject, will form but an inconsiderable portion of the entire course.

The outline of the classification which I propose to adopt, is as follows: Matter will be arranged under the two grand divisions of imponderable and ponderable substances. The first division will be introduced by some

general observations on the nature of imponderable matter, and the laws which may be supposed to govern its reactions. The individual substances included in this division, with the exception of light, will be treated of in the following order:—1st. heat or caloric; 2d. electricity and galvanism; 3d. magnetism and electro-magnetism. Light, though influential in many chemical changes, belongs, as a distinct subject of study, rather to natural philosophy than to chemistry.

The subject of the ponderable substances will be opened with an account of the laws which govern the reactions of that kind of matter. In this place will be discussed successively, chemical attraction, the laws of combination, and the atomic theory. Here it will be explained that the simple bodies, when they unite in the lowest proportion, combine in quantities which are invariable ratios; and the numbers expressing these ratios, do not merely form a chain, but a chain the extremities of which fit exactly. They form, as it were, a circular chain, and hence they express the proportion in which the bodies to which they are attached combine, taken in any possible order. This property of the combining numbers is happily expressed by calling them equivalents. Whenever the proportion in which two bodies combine, deviates from the equivalents expressed in the lowest terms, that is, from the prime equivalents, the deviating numbers are invariably found to be even multiples of the prime numbers. These curious laws of combination are most satisfactorily explained by supposing that the bodies unite by their ultimate particles or atoms, assumed to have different weights, and to be physically incapable of division.

Whether the equivalent numbers can be expressed by whole numbers or not, depends entirely on their relations to each other when correctly ascertained. If they are all found to be susceptible of division by the same number, whether whole number or fraction, without a remainder; then it follows that they may be expressed by whole num-

bers. It is a great mistake, however, to suppose, as some chemical students have done, that abandoning whole numbers to express the combining ratios, is a virtual abandonment of the law that the combining numbers possess the equivalent property. A little reflection will satisfy every one that this is not the case; for the invariable and reciprocating property of the combining ratios, which constitutes their equivalent property, can belong as well to fractional numbers as to whole numbers.

But while it is thus apparent that the equivalent property of the combining numbers, is not in the least affected by their being expressed in fractional numbers; still it may be well to inquire whether they are not, after all, whole numbers; or, which is the same thing, numbers which may all be divided by the same number without a remainder.

In examining this question we shall use the fractional equivalents on the oxygen scale, as given by Berzelius, and assume them to be the precise numbers obtained by experiment. Now it is plain, that in dividing these numbers by any given number, the greatest possible deviation in the quotient from a whole number would be five-tenths, or the half of unity. Here the question arises, will a deviation equal to five-tenths, or approaching to five-tenths, disprove the whole number principle? The proper answer to this question will depend upon the amount of the quotient; for if this be a large number, five-tenths will bear so small a proportion to the entire number that the deviation would form an amount within the limits of error in analysis. On the other hand, if the quotient be a small number, say, for example, under fifteen, then a deviation of five-tenths, or even of one-tenth from a whole number, would disprove the whole number principle; because the deviation would be greater than could be attributed to an error of analysis. If these views be correct, it follows that to test the truth of the whole number principle, the smaller fractional equivalents should be chosen for division. Ac-

cordingly, we shall select the fractional equivalents, given by Berzelius, for carbon, oxygen, and nitrogen, and divide them all by his fractional number for hydrogen, which has the effect of making hydrogen unity. Proceeding thus, carbon comes to be represented by 6·12, oxygen by 8·01, and nitrogen by 14·18. Here oxygen might be safely assumed as the whole number 8, instead of 8·01 ; but carbon could not be taken as 6 instead of 6·12, nor nitrogen as 14 instead of 14·18; for the excess in these cases above the whole number is too great to be neglected. If, therefore, Berzelius's numbers are to be assumed as the nearest experimental approximations to the truth yet obtained, the whole number principle is disproved. But recent researches have called in question the entire accuracy of Berzelius's numbers. Dumas, a chemist who has distinguished himself in organic analysis in France, as Liebig has in Germany, has instituted a series of experiments to determine, among other matters, the more exact equivalents of carbon and nitrogen, and fixes on 6 for carbon, and 14·04 for nitrogen. Thus the progress of investigation evidently tends to confirm the truth of the whole number principle; and taking Dumas' recent corrections, we have, on the hydrogen scale, carbon represented by 6, oxygen by 8·01, and nitrogen by 14·04. Is it reasonable, I ask, to suppose that the coming out of the equivalent of carbon as 6, after the execution of elaborate experiments to determine the point, is a mere coincidence; or that the near approach of 8·01 and 14·04 to whole numbers is merely accidental? Assume for a moment that whole number equivalents are an exact representation of the truth, could we expect to obtain them exactly by experiment; or, rather, would not our experimental results approach to whole numbers, without exactly coinciding with them? The bulks or volumes in which gases combine, are admitted to coincide with the whole number principle. Thus one volume of oxygen is universally conceded to unite with two volumes of hydrogen to form water ; but still it is not contended that the

experimental results obtained are exactly those relations by volume. Admitting for a moment that the relation of the oxygen to the hydrogen in bulk, as one to two, is the true relation, still we could not obtain it exactly by experiment, except by accident. Now, Berzelius himself admits the whole number relation of combining volumes, though not obtained precisely by experiment; and why should we not admit the whole number relation of combining weights, when the numbers obtained are very near whole numbers? Why should we insist on rigid experimental results in the one case and not in the other?

These are the arguments in brief which lead me to suppose that the whole number principle of the combining weights is a true representation of nature. But even if it were not so, I should still consider the whole numbers as sufficiently near approximations to the truth, to use them in teaching the principle of the equivalent numbers to my class. Accordingly, I shall always employ whole numbers to express equivalents; not merely because I consider them as sufficiently exact, but because their use will facilitate your studies. It is as if a teacher of geography had accurately measured the distances between our large cities in miles and decimals of the mile, and yet, in instructing his pupils, should throw off the decimals, and merely mention the even number of miles, as sufficiently near the truth for all useful purposes.

As connected with the subject of equivalents, or atoms, it may be proper, in this place, to explain what is meant by the expression, *isomeric bodies*. It was originally supposed that the same elements, united in the same proportion, necessarily gave rise to the same compound. Latterly, this proposition has been found not to be universally true; for, in some instances, two compounds will agree, precisely, in the elements present in them, and in the proportion in which they are united, as also in their equivalent, that is, in the relative amount in which they unite with equivalent quantities of other bodies; and yet be perfectly dis-

tinct in their properties. This general fact, however unexpected its discovery, is by no means inconsistent with the admitted principles of atomic combination; for it is readily conceivable that the same number of atoms of several different elements, may unite in a great many different orders, so as to produce different compounds. Now, substances which thus agree in composition and in their equivalent, are said to be *isomeric*, from Greek words signifying equal parts, in allusion to the identity of the ratio in which their elements are combined; and the general fact that substances are capable of having this relation to each other, is called *isomerism*. Sometimes the relation between bodies is not so intimate as is here described. Isomeric bodies have the same composition and the same equivalent; but sometimes bodies are related to each other by identity of composition, while their equivalents, instead of being the same, are even multiples or submultiples of each other. Bodies, when thus related, are said to be *polymeric*.

As examples of the isomeric relation, we may mention the two kinds of peroxide of tin; the three kinds of phosphoric acid; hydrated cyanic acid with cyamelide; hydrated saccharic acid with hydrated mucic acid; and formic ether with acetate of oxide of methule. Instances of compounds polymeric with one another, are tartaric with paratartaric acid; urea with carbamid; alcohol with oxide of methule; cyanic acid with fulminic and cyanuric acid; and methylene with olefiant gas, pure oil gas, naphthene and cetene. The five last named polymeric bodies are supposed to be represented in composition, as follows:—methylene by two equivalents of carbon and two of hydrogen; olefiant gas, by four equivalents and four equivalents; oil gas, by eight and eight; naphthene, by sixteen and sixteen; and cetene, by thirty-two and thirty-two. The carbo-hydrogens form a very numerous class, and that division of them which contains an equal number of equiva-

lents of carbon and hydrogen, may be conveniently called *iso-equivalent* carbo-hydrogens.

After having explained the laws of combination, the atomic theory, and the use of symbols, I shall treat of the pressure of the atmosphere and specific gravity. We shall then be prepared to consider the individual ponderable bodies. These will be divided, as is customary, into the non-metallic elements, and those which are metallic. The non-metallic class will be first taken up, comprising oxygen, hydrogen, nitrogen, sulphur, selenium, phosphorus, chlorine, iodine, bromine, fluorine, carbon, boron, and silicon. The metallic class will be divided into those metals which form salifiable bases with oxygen, and those constituting acids with the same element. This part of the arrangement will facilitate the comprehension of the two chief classes of *primary* compounds, namely, acids and bases, which, by their combination, form the *secondary* compounds, known under the name of ordinary salts.

The determination of the atomic constitution of salts, and of other compounds, has been very much aided by an interesting discovery, made many years ago by Mitscherlich, of Berlin. Allusion is here made to his observation, that certain substances are prone to crystallize in the same form. Such substances are said to be *isomorphous*. Now there are several series of salts that are isomorphous with one another. Thus, every phosphate has a corresponding arseniate, and every sulphate, a seleniate, precisely agreeing in crystalline form, and not to be distinguished from each other by their physical properties. It is presumed that the reason why isomorphous bodies have the same form, is because they contain isomorphous elements, united in precisely the same manner. Acting on this reasonable presumption, chemists are accustomed to infer the atomic constitution of an *obscure* compound from the *well-known* constitution of some other compound, with which it is isomorphous. Thus, alumina is isomorphous with the red oxide of iron; for they both form similiarly shaped salts, and

are capable of replacing each other in certain combinations. But the red oxide of iron, from its relation to the other ferruginous oxides, and from other concurrent evidence, is known to be a sesquioxide,—that is, a compound of two atoms of iron with three of oxygen; and alumina, on the evidence of isomorphism, is inferred to be a sesquioxide also. Once admitted to be a sesquioxide, and we have it in our power, from the analysis of alumina, to calculate the atomic weight of its radical, aluminium. Thus, guided by the light afforded by isomorphism, the atomic constitution of many salts, and of the acids and bases which they contain, is determined with much probability.

I shall not attempt to treat of compound bodies according to any precise system of classification. Some of them, as the oxides, sulphurets, phosphurets, carburets, &c., are always treated of in connection with the simple body which forms the radical of each; while others, as the acids, salifiable bases, and salts, are frequently taken up in distinct classes. The plan which I shall generally follow, in the ensuing course, will be to describe a compound as soon as the student has been made acquainted with its constituents. If the compound should be a salifiable base, the salts which it forms with acids previously described will be noticed, before proceeding to the other primary compounds which the element under consideration may be capable of forming. When a compound, having acid properties, comes to be considered in course, a similar digression will be made, for the purpose of describing the salts which it may form with bases previously described. Proceeding in this way, the student's stock of known compounds will be increased as rapidly as possible, consistently with the principle of avoiding anticipations of the subject.

Having finished the consideration of inorganic bodies, I shall next take up those derived from organized beings. This department is distinguished by the name of *Organic Chemistry*, and is generally divided into vegetable and animal chemistry. In the ensuing course I shall not make

this division, but treat of animal and vegetable substances indiscriminately, according to their analogy of properties or composition. Accordingly, I shall arrange organic substances, whether vegetable or animal, under the four following classes:—1st. organic acids; 2d. organic salifiable bases; 3d. neuter substances, or those which are neither acids nor bases; 4th. colouring substances, or dyes.

The department of organic chemistry, in consequence of the rapid accession of facts which it almost daily receives, presents the greatest difficulties in the way of its successful classification and study. Hence it is that any arrangement of the substances which it embraces, can be viewed only as temporary and provisional, because liable to be set aside by the progress of discovery. One of the most important general facts which has been ascertained, is the existence of certain compound radicals, which are common ingredients in a number of organic substances. Sometimes these compound radicals can be obtained in a separate state; at other times, merely transferred successively to different substances. Cyanogen was the first compound radical observed, and is one of those capable of being isolated. It forms prussic acid with hydrogen; cyanic, fulminic, and cyanuric acid with oxygen; and sulpho-cyanogen with sulphur. The principle, called benzule, is a compound radical of carbon, hydrogen, and oxygen, which has never been isolated; but which may, nevertheless, be transferred to different substances. Thus, this group of atoms, with oxygen, forms anhydrous benzoic acid; with hydrogen, hydruret of benzule, that is, the essential oil of bitter almonds; and with sulphur, the sulphuret of benzule. Again, ethule is a compound radical of carbon and hydrogen (not separable, but only transferable), which forms ether with oxygen, and alcohol with oxygen and water. Thus ether is considered to be an oxide of ethule, and alcohol a hydrated oxide of the same principle.

In not a few instances, organic compounds may be represented, in their composition, by two other compounds,

into which they may be resolved by the influence of heat, or by the chemical agency of some other body. Such changes are called chemical *transformations*. Thus oxalic acid, considered dry, corresponds, in composition, with carbonic oxide and carbonic acid gases; and its elements appear to be held together by water; for when the crystals are subjected to sulphuric acid, which abstracts the water, the oxalic acid is transformed into the gases mentioned.

Sometimes a chemical compound is decomposed in such a manner as to have one or more of its elements wholly or partially removed, and replaced by an equivalent quantity of some other element. Facts of this kind have been long observed; but it is only within the last few years, during which organic chemistry has made so rapid a progress, that the importance of the general fact has been properly appreciated. It is to Dumas, particularly, that we owe our present enlarged knowledge of this class of changes, which are known under the name of chemical *substitutions*. The majority of the instances of substitution, has, up to this time, been afforded by the action of chlorine on organic compounds; during which action it is found that this element takes the place, atom for atom, of hydrogen. Sometimes the whole of the hydrogen is replaced; at other times there are numerous new compounds formed by the successive replacement of each atom of hydrogen by an atom of chlorine. In the mean time, the original compound often preserves its leading chemical characters. But it is found that not merely one element of a compound may be replaced by another. In some instances, indeed, all the elements are successively replaced; so that the new compound contains not a trace of the original substance from which it was formed. From these brief explanations it is evident that all the new compounds formed by substitution will contain the same number of atoms as the original compound; and it is inferred by Dumas that they all agree with the original compound in having the same structure; that is, the same arrangement of the atoms. The particular arrangement, thus assumed

to pervade the entire series of compounds, obtained by substitution, is called by Dumas the *chemical type* of the series.

Considering the vast number of organic substances which have latterly been described, and taking into view the received opinions as to the principles of atomic union, which hardly limit the possible combinations, or the number of atoms of an element which may unite,—it can readily be inferred that these substances, if all known, would be exceedingly numerous. Taking the four elements, nitrogen, carbon, hydrogen, and oxygen, which are chiefly present in organic matter, and supposing them, or any two or three of them, combined in all possible numbers of atoms under ten for each element; then the compounds capable of being formed, will not fall far short of 10,000; but, since it is admitted that the elements mentioned may combine in a number of equivalents, greater than 9, and many such compounds have already been discovered, it will be readily perceived how greatly the sum total of organic compounds may be increased beyound the number stated. These considerations teach us how important it must be to have some concise way of denoting the composition of organic substances, and their ready transformation into new compounds. Now this desideratum is attained by the use of chemical symbols, which are simply the initial letter, or two letters, taken from the name of each element, in order to represent it. These are written down in succession, according to the number of elements in any given compound; the equivalents or atoms present of each element being indicated by figures, arranged in a particular way, very easy of comprehension, and readily applied by a little practice. For the introduction of symbols, as a means of representing chemical combinations, we are indebted to Berzelius; and the comprehension of them by the student is absolutely necessary, in order to enable him to understand modern treatises on chemistry, and the chemical papers which appear in the periodicals of the day.

It is now many years since I adopted a plan for recording, in a compact form, all the organic compounds formed by nitrogen, carbon, hydrogen, and oxygen, within the limits of nine equivalents of each element. The plan consists in writing down, in succession, all numbers from 11 to 10,000. This, of course, furnishes a table, containing every possible permutation of the ten figures used in arithmetic, between the limits above named. The arrangement gives four columns of figures, which I head from left to right with the symbols of nitrogen, carbon, hydrogen, and oxygen. Of course, any combination of figures in the table will indicate a compound containing, of each element at the head of the column, the number of atoms which the several figures denote. Substances which contain one or more elements, in an amount represented by a number of atoms greater than nine, I place in a supplementary table; but such of these substances as admit, when their equivalents are reduced to the lowest terms, of being brought within the range of numbers in the principal table, are also inserted in this table; the reduced numbers being accompanied by multipliers to afford the means of obtaining the real or supposed equivalents of the substances to which they are annexed. I have found tables thus constructed, useful in indicating, in a methodical form, what organic combinations have been observed, what combinations remain that are possible, but have not yet been discovered, and what compounds are polymeric with one another.

After having passed in review organic compounds, in as much detail as the prescribed limits of the course will permit, I shall next give a sketch of what is known or conjectured in animal chemistry. This department of chemical science has made rapid progress within the last few years, in consequence of the labours of the German chemists, and especially of those of the school of Giessen, of which Liebig is the head. Every one admits that chemical changes are incessantly taking place in living beings, whether animal or vegetable. These changes are recognised to be under

the control of a force, not understood, but known through its effects, called the vital force. To admit the existence of such a force, in view of the phenomena exhibited by living beings, is not assuming more than we assume when we speak of an electrical force, a magnetic force, &c. Whether we shall ever arrive at a true knowledge of the laws of the vital force is very uncertain; still it is only by the path of chemistry, that we can hope to make any solid progress in their investigation.

In a full grown animal, the materials of the organs are constantly undergoing waste, and as constantly reproduced; and in the most perfect health, the waste and reproduction are in equilibrium. The waste is caused by all the actions of the system; the reproduction is effected by means of the materials furnished by the food. As the vital force can produce no chemical element, it is plain that the food must contain the elements of all the solids and fluids of the body. Now, the investigations of Liebig have been mainly directed to determining, what are the principles of nutrition, what are the products of the wasting, that is, the transformation of the tissues, and what the channels through which these products are expelled. The most influential step made in elucidation of these points, was the discovery of protein by Mulder, a principle which forms the common basis of animal albumen, fibrin, and casein, substances which merely differ in containing more or less of certain mineral substances, always present in minute quantity;—albumen and fibrin being characterized by free sulphur and phosphorus, and casein, by free sulphur and by phosphate of lime. The next important fact was the discovery that vegetable albumen, vegetable fibrin, and legumin are identical severally with animal albumen, fibrin, and casein; since the former contain the same common basis, protein, and the same minute portions of mineral substances. Thus it is that the terms vegetable albumen, vegetable fibrin, and legumin are superseded by the simpler expressions, albumen, fibrin, and casein; all three being modifications of protein, and

all derived, indifferently, from animal and vegetable matter. Next in importance to these substances is gelatin, which is exclusively of animal origin; being furnished by the gelatinous tissues when boiled with water, though it does not pre-exist in them. Gelatin is peculiar in not yielding protein, and, therefore, cannot be classed with albumen, fibrin, and casein. These three substances are considered by Liebig as the sources of animal nutrition, and, being all modifications of protein, are assumed by him to be readily convertible into each other. In the case of carnivorous animals, these substances form the food; and they furnish the blood directly, without any transformation, other than that of being converted into each other, a conversion of which they are assumed to be easily susceptible, as modifications of protein. The waste of the tissues is repaired by the blood, and the elements resulting from their waste are considered by Liebig to furnish the bile and urinary secretion. As the tissues are thus admitted to be renewed by the blood, they may be assumed to be identical, in composition, with that fluid. It, therefore, follows that the bile and urine (if they correctly represent the elements separated from the wasted tissues,) must likewise be identical, in composition, with the blood. Now Liebig has shown that half the formula of choleic acid, which is the chief organic constituent of the bile, added to the formula of urate of ammonia, the chief material furnishing the urine, gives a sum which exceeds the formula of *dried* blood, only by one equivalent of oxygen, and one of water; and free oxygen and water are always present in *liquid* blood. This ingenious theory forms the first attempt that has been made to trace, chemically, the connection between the blood, the tissues, and the secretions and excretions. In regard to the ultimate disposition of the bile and urate of ammonia, Liebig conceives that the former passes into the blood by absorption, and is oxidized, that is, burned as it were, by the free oxygen of the blood-globules; the products, carbonic acid and water, being expelled chiefly

through the channel of the lungs in respiration. The oxidation of the bile in the way here described, which is equivalent to the combustion of its carbon and excess of hydrogen, is considered by Liebig as the main source of animal heat; and admitting this view, it shows that a large portion of the consumed tissues is not expelled at once; but, being elaborated into bile from the blood, is taken back into that fluid, and passes out of the system finally in another form, with the incidental effect, in the process of elimination, of generating animal heat. The formerly received opinion was that bile is expelled with the excrementitious matters; but both Berzelius and Liebig have shown that but a small portion of this secretion can be detected in these products, a fact which favours the opinion that it is reabsorbed, as asserted by Liebig, to be burned in passing the round of the circulation. The urate of ammonia, the other product of the consumed tissues, is sometimes expelled unchanged in the form of solid urine, as in serpents and birds; but in man and quadrupeds, according to Liebig, it is oxidized, yielding, finally, carbonic acid to be expelled through the lungs, and ammonia and urea to pass by the urine. These transformations are also a source of heat; for, during oxidation, however effected, caloric is necessarily given out.

The preceding remarks apply to the carnivora. In the herbivora the food consists not merely of the nitrogenized protein-compounds, the materials of nutrition in the strict sense, but also of certain non-nitrogenized principles, of which starch, sugar, and oily substances are the chief. If animals are nourished exclusively by the protein-compounds, it may be asked, what purpose can be answered by non-nitrogenized substances as food? Liebig answers this question by alleging that these substances are not destined to repair the waste of the tissues, but to furnish materials which may form the source of animal heat, by their oxidation or combustion. The bile of the herbivora is more abundant than that of the carnivora; and the waste

of the tissues, which is slow in the former, is inadequate to furnish the whole of it. The starch and other non-nitrogenized materials of the food of the herbivora, are, therefore, supposed by him to unite with some nitrogenized product of the protein-compounds, so as to form the materials of both bile and urine in these animals. In support of this view, Liebig shows how the elements of protein and starch, when taken together, may possibly undergo transformation, so as to produce choleic acid, urea, &c.

In the carnivora, Liebig supposes that no substances are taken as food, specially intended to sustain the animal heat, independently of the object of repairing the waste of the tissues. On this view, the carbon derived from the wasted tissues, is, by its oxidation, the sole source of heat in these animals; and in order that the supply of this element may be sufficient, the tissues must be rapidly consumed, and this is accomplished, according to Liebig, by the incessant muscular motion of the carnivora.

In man, as an omnivorous animal, the waste of the tissues is repaired by the protein-compounds, chiefly in the form of animal food, and the heat sustained by the oxida tion of non-nitrogenized substances, as in the herbivora. Gelatin, not being a modification of protein, is held by Liebig not to be a principle of nutrition. He admits that it may possibly serve, directly to nourish the gelatinous tissues, but denies that it can form blood or muscular fibre. Liebig supports these assertions by adducing the well established fact, that dogs, fed exclusively on gelatin, die with symptoms of starvation. But, it may be asked, are we sufficiently acquainted with the laws of nutrition to assert that a substance is not nutritious because it will not support animal life when exclusively given? Is it not possible, nay probable, that, even in carnivorous animals, a mixture of proximate principles in the food is necessary to sustain life? Tiedemann and Gmelin found that geese could not be sustained by boiled white of egg, in other words albumen; but Liebig attempts to explain away this fact, by alleging that this animal cannot obtain

from the waste of the tissues alone, sufficient carbon to sustain, by its oxidation in the respiratory process, the animal heat. Animals are perfectly nourished by food containing the protein-compounds, without gelatin; and hence it is necessary to assume that the protein-compounds can be converted into gelatin under the influence of the vital force, in order that the appropriate substance to nourish the gelatinous tissues may be formed. This is contended for by Liebig; and to sustain his opinion he indicates two ways in which protein may be converted into gelatin; namely, either by the separation of carbon, or by the addition of nitrogen, hydrogen, and oxygen. But, it may be asked, why may not the converse operation take place; and if we admit that the vital force can convert protein into gelatin; why not concede that the same force can change gelatin into protein, which is equivalent to its change into blood? Liebig has here certainly erred, in limiting the transforming powers of the digestive and assimilating organs. There can be no doubt that those substances are most proper for food, and most easily digested, which yield readily to transformations, such as albumen, fibrin, and casein; but suppose gelatin, which contains an excess of nitrogen, compared with protein, and is, moreover, devoid of mineral elements, were taken as food, associated with vegetable substances, fitted to supply the mineral elements, and the deficient carbon, hydrogen, and oxygen,—is it reasonable to assume that the digestive and assimilating organs are inadequate to mould these materials into healthy blood? That gelatin may be digested, is certainly a more reasonable supposition than that it passes unaltered into the blood, to be appropriated directly to the nourishment of the gelatinous tissues.

I have thus, gentlemen, presented you with an outline of he course of lectures which I propose to deliver in this College. In giving it I have indulged in occasional digressions, in order to explain several difficult points of

chemical doctrine. You are not, however to view these digressions as a foretaste of abstruse disquisitions which I shall enter upon in my lectures. On the contrary, it is precisely because I wish hereafter to avoid treating of these difficult points, that I have introduced them into this address. The passing remarks which I have made on the new views of Liebig in physiological chemistry, may not be without their use; as they may serve to awaken inquiry, and to facilitate your future studies. Without doubt Liebig's physiological speculations are well worthy of your attention; but allow me to caution you against adopting them on trust, and without rigid examination. Let us be grateful to him and his coadjutors for the multitude of exact organic analyses which they have contributed; let us freely admit that they have shed much light upon particular points of physiology; but let us not at the same time be deceived into the belief that they have demonstrated the manner in which the nutrition and transformation of the tissues take place. It may be that they have lifted a corner of the curtain which conceals from our view what is performed on the stage of the vital organism; but let us be careful how we admit their presumptuous claim that they have penetrated behind the scenes, and witnessed nature in the very act of playing her part in the mysterious drama of life.